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In re patent application of

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For: REFRIGERANT CIRCUIT AND A REFRIGERATING SYSTEM

VERIFICATION OF TRANSLATION

Commissioner for Patents
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I, Susan ANTHONY BA, ACIS,

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Date: October 27, 2004

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# Refrigerant circuit and refrigerating system

The invention relates to a refrigerant circuit with heat receivers and with heat emitters and to a refrigerating system with a refrigerant circuit.

Refrigerant circuits of this type are used in refrigerating systems, such as, for example, air conditioning systems, in order to transport heat from at least one first spatial region into at least one second spatial region, in particular with a temperature level equal to or higher than that of the first spatial region. The refrigerant in this case receives heat in a heat exchanger, operated as a heat receiver, in the first spatial region, and is conducted to a heat exchanger, operated as a heat emitter, in the second spatial region, in order to emit heat there.

In order to allow the transport of heat from a relatively colder to a relatively warmer spatial region, the refrigerant is conventionally conducted in an expanded state, that is to say at a lowered temperature, through the heat receiver and in a compressed state, that is to say at an increased temperature, through the heat emitter. For this purpose, the refrigerant circuit comprises a compression element, such as, for example, a compressor, and an expansion element, such as, for example, an expansion valve, so that the refrigerant

flows through the circuit in the sequence: compression element - heat emitter - expansion element - heat receiver.

Condensers, in which the refrigerant condenses, with heat energy being emitted, are often used as heat emitters, the temperature of the refrigerant changing only insignificantly during the condensation phase transition. Similarly, what are known as refrigerant evaporators, in which the refrigerant is evaporated, are frequently used as heat receivers, the temperature of the refrigerant likewise changing only insignificantly during the evaporation phase transition. However, since refrigerant circuits are sometimes also operated without phase transitions of the refrigerant, the terms "condenser" and "evaporator" are, in part, misleading and, apart from special examples, will not be used here.

In the case of a given refrigerant, the temperature levels of a refrigerant circuit depend mainly on the pressure levels, basically higher temperatures prevailing on the high-pressure side of the circuit, that is to say in the direction of flow of the refrigerant downstream of the compression element, than on the low-pressure side downstream of the expansion element. If, then, a plurality of heat receivers are to be used in a refrigerant circuit, the pressure conditions on the low-pressure side of the circuit have to be adapted to the heat receiver having the lowest desired operating temperature, since, at higher temperatures, this heat receiver could not receive sufficient heat energy. If, in the case of a further heat receiver, a higher temperature is desired or is sufficient, it is thermodynamically inefficient to operate this further heat receiver at a low temperature. The corresponding consideration also applies in a similar way to heat emitters.

The object of the invention is, therefore, to provide a refrigerant circuit and/or a refrigerating system, in which a plurality of heat receivers and/or a plurality of heat emitters can be operated in each case at different temperatures.

This object is achieved by means of a refrigerant circuit having the features of claim 1 and by means of a refrigerating system having the features of claim 16.

According to claim 1, a refrigerant circuit has at least one heat receiver, in which heat can be received from a refrigerant, and at least one heat emitter, in which heat can be emitted by the refrigerant. The object of the invention is advantageously achieved in that a plurality of functionally identical heat exchangers, that is to say a plurality of heat receivers or a plurality of heat emitters, can be operated at a different refrigerant pressure. As a result, the basic idea of the invention, to be precise to adapt the operating temperatures of a plurality of functionally identical heat exchangers to different requirements, can be implemented in a simple way.

Within the scope of the present invention, those heat exchangers are to be considered as functionally identical heat exchangers which, while the refrigerant circuit is in operation, simultaneously fulfill the same function, that is to say either a heat transfer from a medium to the refrigerant or from the refrigerant to a medium. What may be considered as a medium in this case is, for example, a liquid, gaseous, supercritical or any other fluid, just as well as, for example, a solid or an in particular heat-generating device or even combinations of these. The functional identity of two heat exchangers is not affected by possibly different functions, which two or more heat

exchangers fulfill at different time points, for example in different operating modes of the refrigerant circuit.

Within the scope of the present invention, two refrigerant pressure levels are different from one another when the difference between the pressure amounts of the individual levels is greater than a pressure drop which normally occurs, for example, along refrigerant lines or heat exchangers. In particular, two heat exchangers directly connected in series hydraulically cannot be operated at different refrigerant pressure levels, insofar as no conveying or throttling means for the refrigerant are provided in or between the two heat exchangers. By contrast, a pressure difference caused by a compression element or by an expansion element is highly suitable for generating two different refrigerant pressure levels within the scope of the invention.

What is designated as a compression element is any device which is suitable for conveying refrigerant from one location of a circuit to another location of the circuit having a higher pressure, that is to say for the compression of refrigerant. Compressors and pumps are examples of compression elements.

What is designated as an expansion element is any device which is suitable for generating a pressure drop between one location of a refrigerant circuit and another location of the circuit, that is to say for the expansion of refrigerant. Externally activatable and nonactivatable expansion valves and also throttles are examples of expansion elements, any contraction in the refrigerant circuit, for example a tube of small diameter between two heat exchangers, being suitable, where appropriate, as a throttle. Under some circumstances, a flow diameter reduced to half is

sufficient for a desired contraction, that is to say a contraction which is suitable in this sense as a throttle.

In order to achieve a compact type of construction, it is advantageous to combine a compression element and/or an expansion element structurally with a heat exchanger. For example, a throttle can be integrated into a heat exchanger in a simple way. If a heat exchanger has a plurality of flow paths connected in series hydraulically, then a throttle integrated into the heat exchanger can also be implemented by means of a reduced number of flow ducts which, in particular, form the first or last flow path of the heat exchanger and are hydraulically parallel to one another.

According to an advantageous refinement, a first heat receiver, a second heat receiver and a heat emitter can be operated at three different pressure levels, the first heat receiver being operable at a higher pressure than the second heat receiver. This ensures two different cooling temperature levels, with a heat emission temperature independent of these. In particular the first and the second heat receivers are connected hydraulically in parallel, each of the two heat receivers being preceded and/or followed by its own expansion element, so that the heat receivers can be acted upon with refrigerant at different pressure levels. Under some circumstances, it is sufficient if only the first or only the second heat receiver is preceded or followed by an expansion element. In another version, a first and a second heat receiver are connected hydraulically in series, in which case a pressure difference can be implemented by means of an interposed expansion element.

According to a preferred embodiment, a first heat receiver and a heat emitter can be operated at a common

pressure level. This avoids the need for additional compression and/or expansion elements and for a resulting outlay in terms of manufacture, of assembly and of cost. The operating temperature of the first heat receiver corresponds at least approximately to the operating temperature of the heat emitter.

Particularly preferably, a compensation element for the refrigerant, such as, for example, a collecting container, in which, if appropriate, a filter element and/or a drier can be received, is arranged downstream of the first heat receiver. The compensation element is in this case constructed essentially in the same way as a compensation element conventionally following a heat emitter and serves for the collection and, if appropriate, phase separation of the refrigerant, so that only liquid refrigerant is supplied to an expansion element.

According to a preferred development of the refrigerant circuit, the first heat receiver is arranged hydraulically between two portions of the heat emitter. This means that refrigerant, after flowing through a first portion of the heat emitter, is conducted through the first heat receiver and is subsequently returned into the heat emitter where it flows thereafter through a second portion.

In one embodiment, the entire refrigerant stream is in this case routed through the first heat receiver. In a further version, only part of the refrigerant stream is routed through the first heat receiver, while another part of the refrigerant stream is conducted through a bypass connection from the first to the second portion of the heat emitter. Particularly preferably, the bypass connection comprises a third portion of the heat emitter, so that, after the first portion, the refrigerant flows either through the first heat

receiver or the third portion of the heat emitter and, finally, through the second portion.

According to a preferred refinement, the first heat receiver forms, with a portion of the heat emitter, a closed subcircuit. The refrigerant is then extracted from a main circuit, downstream of the heat emitter portion, routed through the first heat receiver and supplied to the main circuit again, upstream of the heat emitter portion. In particular, the subcircuit contains a compression element and an expansion element, for example the compression element also serving as a compression element of the main circuit. Preferably, however, the closed subcircuit is located within a pressure level, that is to say no compression or expansion elements are contained in the subcircuit.

According to an advantageous development, the first heat receiver is arranged so as to be geodetically lower than the heat emitter portion of the subcircuit. Refrigerant which receives heat in the first heat receiver, that is to say is heated, rises upward and enters the heat emitter portion, in order to emit heat there, that is to say be cooled, and to fall downward again to the first heat receiver. No compression element is required for such a natural circulation, as it is known, and therefore this heat transport takes place even when a compression element is either switched off or is not present at all. Under some circumstances, therefore, heating or cooling may be carried out with an energy saving. In order to assist the natural circulation with regard to a flow resistance of the subcircuit, particularly preferably an additional refrigerant conveying device, such as, for example, a liquid pump, is provided, by means of which a pressure drop along the refrigerant subcircuit can be compensated.

Another advantageous development makes use, to maintain a refrigerant stream in the subcircuit, of a suck-off element, via which the first heat receiver communicates with the main circuit. The suck-off element, which is designed, for example, as what is known as a Venturi tube or the like, in this case sucks off refrigerant from the first heat receiver and supplies it to the main circuit. A pressure drop along the refrigerant subcircuit is thereby likewise compensated or overcompensated. The suck-off element can advantageously be integrated into a heat emitter.

According to a preferred embodiment of the refrigerant circuit according to the invention, at least one heat receiver forms, with at least one heat emitter, a structural unit. Particularly in the case of identical or similar refrigerant pressure levels, and consequently identical or similar operating temperature levels, simplified mounting in a predetermined construction space can be implemented by means of such a combined component.

According to a further embodiment, at least one heat receiver can additionally be cooled. This means that only part of the heat energy received is transferred to the refrigerant and transported away and part is emitted directly to a cooling medium, such as, for example, air flowing past.

According to an advantageous embodiment, heat energy from a medium of a secondary circuit is received by at least one heat receiver which, particularly in the case of a higher refrigerant pressure, can be operated as at least one further heat receiver, the secondary circuit being particularly preferably a cooling circuit. Indirect cooling of one or more heat-generating components thereby becomes possible.

According to a preferred version, a first heat receiver is designed as a cooler for electronic components. Particularly preferably, a second heat receiver is designed as cold generator of an air conditioning system, in particular for motor vehicles. The idea of the invention becomes noticeable particularly clearly here, since cold generators of air conditioning systems are conventionally operated at markedly lower temperatures than coolers of electronic components. It is therefore particularly advantageous, in this case, to operate two heat receivers at different pressure levels.

According to a preferred development, the refrigerant circuit according to the invention is inserted into a refrigerating system, in order to cool or to heat a plurality of components at different temperature levels.

The invention is explained in more detail below by means of exemplary embodiments, with reference to the drawings in which:

fig. 1 shows a diagrammatic view of a refrigerant circuit according to the present invention,

figs. 2-8 show in each case a diagrammatic view of a refrigerant circuit, and

fig. 9 shows a diagrammatic view of a secondary circuit.

Fig. 1 illustrates a diagrammatic view of a refrigerant circuit 10. A compression element 20 and an expansion element 30 delimit a high-pressure side 40 and a low-pressure side 50 of the circuit 10. Consequently, starting from the compression element 20, the refrigerant flows counterclockwise through the circuit

10. As a result of compression in the compression element 20, which is designed, for example, as a compressor, the temperature of the refrigerant increases, whereupon heat from the refrigerant is emitted in a heat emitter 60 to air, indicated by arrows 70, which is flowing past.

The refrigerant subsequently flows through a first heat receiver 80, in which it receives heat from a component to be cooled, not shown, such as, for example, an electronic control device or the like. The refrigerant is thereafter intercepted in a compensating or collecting container 90 and supplied to the expansion element 30 where it enters the low-pressure side 50.

As a result of expansion in the expansion element, the temperature of the refrigerant decreases markedly, so that, in a second heat receiver 100, a further component, not illustrated, such as, for example, an air stream or the like, can be cooled, with heat energy being received. The cooling temperature of the component cooled by the heat receiver 100 located on the low-pressure side is in this case markedly lower than the cooling temperature of the component cooled by the heat receiver 80 located on the high-pressure side, since the heat receiver can be operated at the pressure level of the heat emitter. By the refrigerant being conducted further on to the compression element 20, the refrigerant circuit 10 is closed.

If the refrigerant circuit 10 is operated with a two-phase refrigerant, such as, for example, R134a, the difference in the temperature levels on the high-pressure side 40 and on the low-pressure side 50 is particularly pronounced. In a design of the circuit 10 for conventional air conditioning systems, the temperature of the two-phase range of the refrigerant is, as a rule, in the region of 40°C to 70°C on the

high-pressure side, but in the region of 0°C on the low-pressure side. The heat receiver 100, then operated as an evaporator, on the low-pressure side is suitable for the cooling of air for the air conditioning of a space, for example of an interior of a motor vehicle, and the heat receiver 80 on the high-pressure side is adapted to a preferred cooling temperature of electronic components, such as control units and the like. The refrigerant expanded in the expansion element 30 is therefore evaporated in the evaporator 100, compressed in the compressor 20, condensed in the heat emitter 60, then active as a condenser, at least partially evaporated again and/or heated in the heat receiver 80 and, finally, intercepted in the compensating element 90 where the gaseous fraction is separated.

Fig. 2 shows a refrigerant circuit 110 with a compression element 120, a heat emitter 130, a first heat receiver 140, a compensating element 150, an expansion element 160 and a second heat receiver 170. Here, refrigerant flows through a first portion 180 of the heat emitter 130, subsequently through the first heat receiver 170 and thereafter through a second portion 190 of the heat emitter 130. The entire refrigerant in this case flows through the first heat receiver 170.

If the desired cooling temperature of the first heat receiver 140 is lower than the operating temperature of the heat emitter 130, the pressure level of the first heat receiver and consequently also of the second portion 190 of the heat emitter 130 is lowered, if appropriate, with the aid of an expansion element 200. In the simplest instance, the expansion element 200 is formed as a throttle by means of a small orifice through which the refrigerant must pass, in which case the orifice may be arranged, for example, in a

partition of a collecting box of the heat emitter 130. In the case of a heat emitter with heat exchanger tubes interconnected in a serpentine-like manner, it is possible to implement the throttle action by means of a reduced number of tubes or ducts of multichamber tubes, that is to say by means of a reduced flow cross section, in a serpentine segment, in particular in the last serpentine segment of the first heat emitter portion 180. It is likewise possible to use an externally controllable expansion valve as an expansion element 200, with the result that the operating temperature of the first heat receiver 140 can be adapted to requirements varying in time.

In a similar exemplary embodiment, which is not pictured, the compensating element, for example designed as a collecting container and, if appropriate, equipped with a filter unit and/or drier unit, forms, with the heat emitter, a structural unit, the refrigerant, after flowing through the compensating element, being routed through what is known as a supercooling portion of the heat emitter. This variation, which is also basically possible in the other exemplary embodiments listed, without departing from the scope of the present invention, makes it possible here to connect the first heat receiver and the compensating element in succession, so that the second portion 190 of the heat emitter 130 from the preceding example (fig. 2) forms the supercooling portion of the unit consisting of heat emitter and of compensating element.

In the refrigerant circuit 210 in fig. 3, a first heat receiver 220 is covered by only one part 230 of the refrigerant stream, whereas another part 240 of the refrigerant stream flows through a third portion 250 of the heat emitter 260, the third portion 250 being arranged between a first portion 270 and a second

portion 280 of the heat emitter 260. Refrigerant coming from the compression element 290 therefore flows through the first portion 270 of the heat emitter 260, is then apportioned to the third portion 250 and the first heat receiver 220 and is subsequently combined again in the third portion 280 of the heat emitter 260. The refrigerant is subsequently again intercepted in a compensating element 300, so that, if appropriate, a gaseous fraction of the refrigerant can be separated.

The refrigerant circuit 310 in Fig. 4 differs from the circuit 210 known from Fig. 3 basically in that the first heat receiver 320 is arranged so as to be geodetically lower than the heat emitter 360, in particular than its middle portion 350 with which the first heat receiver forms a closed subcircuit. As a result, as illustrated in the refrigerant circuit 410 in fig. 5, heat transport from the first heat receiver 420 to the heat emitter 460 or the middle portion 450 of the latter becomes possible, even with the compression element 490 switched off.

Such natural circulation cooling proceeds automatically, since the refrigerant is heated and/or, if appropriate, partially evaporated as a result of heat being received in the first heat receiver 420, rises upward and is cooled again and/or, if appropriate, condensed in the middle portion 450 of the heat emitter 460, after which the refrigerant falls again and arrives at the first heat receiver. The transported heat energy is in this case emitted, for example, to an airstream 470. A cooling action of the first heat receiver 420 is thus maintained, even with the compression element 490 switched off, as, for example, when an air conditioning system is operated in winter. The associated saving of energy is in this case obvious. As compared with operation of the refrigerant circuit 310 (fig. 4) in summer, with the compression

element 390 switched on, however, the direction of flow of the refrigerant through the first heat receiver 420 has been reversed.

In a further exemplary embodiment, not shown, the natural circulation is assisted by a small refrigerant conveying device, such as, for example, a liquid pump, in which case the refrigerant conveying device may be arranged either upstream or downstream of the first heat receiver.

Fig. 6 illustrates a further refrigerant circuit 510 with a heat emitter 540 consisting of a first portion 520 and of a second portion 530, in which refrigerant circuit a first heat receiver 550 forms, with the second portion 530 of the heat emitter 540, a closed circuit. In order to promote a return of the refrigerant from the first heat receiver 550, the first heat receiver 550 communicates with the heat emitter 540 via a suck-off element 560, the suck-off element 560 being designed, for example, as what is known as a Venturi tube, in which the pressure in the line 570 coming from the first heat receiver 550 is lowered within the heat emitter 540 by means of refrigerant flowing past.

Fig. 7 shows a refrigerant circuit 610 with a suck-off element 660. In contrast to the circuit 510 in fig. 6, in which the suck-off element 560 is integrated into the heat emitter 540 between the two portions 520 and 530, the suck-off element 660 is arranged between the compression element 680 and the heat emitter 640. As in fig. 6, the direction of flow of the refrigerant is also indicated in fig. 7 by arrows.

Fig. 8 illustrates, as a further variant, a refrigerant circuit 710, in which a high-pressure side 720 and a low-pressure side 730 are separated from one another by

a compression element 740 and two expansion elements 750, 760. A subcircuit 800 formed by a first heat receiver 770 and a portion 780 of a heat emitter 790 extends in this case onto both sides 720, 730. In the subcircuit 800, the refrigerant is discharged from the first heat receiver 770 by means of the expansion element 750, designed, for example, as a throttle, into the low-pressure side 730, in order, finally, to be compressed by the compression element 740 and supplied to the heat emitter 790. In the heat emitter 790, the refrigerant is apportioned to the subcircuit 800 and a main circuit 810 of the refrigerant circuit 710. A second portion 820 of the heat emitter 790, a compensating element 830, the expansion element 760 and a second heat receiver 840 on the lower-pressure side 730 are located in the main circuit 810.

In a similar exemplary embodiment, a further expansion element is located in the subcircuit 800 within the heat emitter 790 and the first heat receiver 770, so that the pressure and/or the temperature of the heat receiver 770 can, if necessary, be brought to a reduced level, as compared with the heat emitter 790.

In another exemplary embodiment, the second portion 820 of the heat emitter 790 is dispensed with, so that the vanishing-off point of the subcircuit 800 from the main circuit 810 is arranged hydraulically between the heat emitter 790 and the expansion element 760 and upstream or downstream of the compensating element 830.

Fig. 9 illustrates a detail of a refrigerant circuit 910 according to the present invention. A heat receiver 920 is arranged on a high-pressure side of the refrigerant circuit 910 in order to receive heat energy from a secondary cooling circuit 930. The secondary cooling circuit 930 serves in this case for heat transport from a plurality of components 940, 950 and

960 connected in series with or in parallel to one another to the heat exchanger 920 which, in terms of the cooling circuit 930, is a heat emitter. Coolant circulation through the cooling circuit 930 is ensured by a compression element 970 which is designed, for example, as coolant pump. The components 940, 950 and 960 to be cooled are, for example, electronic subassemblies or controls or other heat-generating devices.